VOLUME XXV NUMBER 2 WHOLE NUMBER 201

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PUBLISHED MONTHLY
(Ten numbers per year)

February, 1931

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

THE JOURNAL

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PLATE III

KEPLER'S BIRTHPLACE

The house under the arrow is that in which Kepler was born. It is just off the market place in the midst of which is the monument to Kepler. In the house is now a confectionery shop of which Theodor Koppler is proprietor. (*Photo by C. A. Chant*, 1928.)

PLATE IV

KEPLER'S MONUMENT IN WEILDERSTADT

In the left picture is the monument as decorated for the visit of the Astronomische Gesellschraft in 1928. In the right picture is seen Professor Eddington addressing the gathering. Just at his left, bare-headed, is Professor Strömgren. At the far side with hat in left hand and umbrella in right is the Mayor of Weilderstadt. (*Photo by C. A. Chant*, 1928.)

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JOANNES KEPLER 1571-1630*

With Plates III, IV.

By H. DINGLE

THREE hundred years ago one of the greatest of the world's astronomers died in poverty and neglect at Ratisbon, and on November 15 the little German town of Weilderstadt, in which he was born, witnessed a memorable sight. Not, indeed, a rare one, for Germany honours its great men now, and the statue of Kepler in the market-place of Weilderstadt has received many a tribute from modern Germans to one of whom their fathers were not worthy. The writer has a vivid remembrance of such an event just over two years ago, when the Astronomische Gesellschaft, then meeting at Heidelberg, made a pilgrimage southwards to render homage to their great predecessor. The quaint little town, still whispering the last enchantments of the Middle Age, seemed strangely to unite the mediaeval and the modern, and little imagination was needed to feel the spirit of Kepler brooding over the place—"a presence which was not to be put by."

For Kepler, more than any of the great men of this epoch who ushered in the age of science, harmonized in himself the essential elements of the old and the new ages. Copernicus kept himself too far aloof from the world to inspire in us much more than an academic sympathy. In Tycho Brahe the crassest superstition of the dark ages cohabited with an ultra-modern recognition of the importance of exact measurement, but they held no intercourse: it

*This article appeared in *The London Spectator*. The author is professor of astrophysics in the Imperial College of Science and Technology and secretary of the Royal Astronomical Society, London.—EDITOR.

was a Box-and-Cox-like association which leads us to regard Tycho as almost a dual personality. The miracle that was Galileo, on the other hand, sprang fully developed from the brain of pure science—an immaculate conception almost without parallel in the history of transition movements. But Kepler—mystic, philosopher, scientist, artist—what formula can describe the man whose scientific investigation was religious devotion, to whom observations were sacred, and who would yet refuse to consider a natural interpretation of them if it appeared inharmonious?

There run through all Kepler's works, as inseparable threads of their texture, the search, familiar to the scientist of to-day, for rational co-ordination of observations, and the almost infinite remoteness of a mysticism with which we have lost touch. Even the clearest of his writings is hardly intelligible to us in its completeness on this account. Take, for example, his remarks on the question whether traditional authority or sensory evidence should form the basis of our rationalizing, which was pre-eminently the question at issue in the early seventeenth century:

"Now as touching the opinions of the Saints about these natural points. I answer in one word, That in Theology, the weight of Authority, but in Philosophy the weight of Reason is to be considered. Therefore Sacred was Lactantius, who denyed the Earth's rotundity; Sacred was Ausgustine, who granted the Earth to be round, but denyed the Antipodes; Sacred is the Liturgy of our Moderns, who admit the smallnesse of the Earth, but deny its Motion: But to me more sacred than all these is Truth, who with respect to the Doctors of the Church, do demonstrate from Philosophy that the Earth is both round, circumhabited by Antipodes, of a most contemptible smallnesse and in a word, that it is ranked amongst the Planets."

Who else could give us such a reconciliation as this?

Kepler was born in 1571, a premature, sickly child, into a household torn asunder by violent quarrels. Illness and family misfortunes robbed him of all but the most fragmentary education in his boyhood, but an eager spirit triumphed over all obstacles, and he obtained the degree of Master at the University of Tübingen in his twentieth year. Three years later the Chair of Astronomy at Gratz fell vacant, and Kepler, with little knowledge of astronomy and no

enthusiasm for it, was forced, as he tells us, to accept the position by the authority of his tutors.

"Not that I was alarmed . . . . by the remoteness of the situation, but by the unexpected and contemptible nature of the office and by the slightness of my information in this branch of philosophy. I entered on it, therefore, better furnished with talent than knowledge; with many protestations that I was not abandoning my claim to be provided for in some other more brilliant profession."

Not a very promising beginning, but a change was imminent. No sooner had he set himself to master his subject than the divine madness seized him, and thenceforth the course of Kepler's life was marked out. He was possessed by the passion of reading the thoughts of God in His handiwork, the heavens. The Pythagorean music of the spheres was not for the sensual ear, but for the ear of the mind, and no one had yet heard it: he would be the first. He thereupon set himself one gigantic task after another, testing possible ideas by comparison with the observations of Tycho, whose assistant he soon became. Any idea that appealed to his sense of harmony was examined and thoroughly tested, however improbable it might appear in the cold light of reason. Would it require years of incessant labor? No matter: amid poverty, family troubles, illness, religious persecution, and failure after failure he followed with undiminished zeal and constant prayer the path which he had chosen. He knew instinctively that Truth was Beauty, but he learned by bitter experience that Beauty might not be Truth.

The mind of Kepler is well illustrated by an anecdote which he gives us in a refutation of the opinion of the Epicurean that a new star which appeared in the year 1604 was a fortuitous concourse of atoms.

"I will tell these disputants, my opponents, not my own opinion, but my wife's. Yesterday, when weary with writing, and my mind quite dusty with considering these atoms, I was called to supper, and a salad I had asked for was set before me. 'It seems, then,' said I aloud, 'that if pewter dishes, leaves of lettuce, grains of salt, drops of water, vinegar, and oil, and slices of egg, had been flying about in the air from all eternity, it might at last happen by chance that there would come a salad. 'Yes,' says my wife, 'but not so nice and well dressed as this of mine is.' "

Here we have the essence of Kepler. It was not the salad, but the well-dressed salad that spoke of the divine Mind. Any monster could make suns and planets, but only God could give them a plan.

After eight years Kepler gave to the world two of the three laws which now bear his name. These laws assert that the planetary orbits are ellipses, and state how the speed of a planet varies as it approaches or recedes from the sun. Further toil followed, and seventeen years after the beginning of his labors he discovered the third law. In his book, *The Harmonies of the World*, he tells us the circumstances of the discovery.

"What I prophesied two and twenty years ago . . . What I firmly believed long before I had seen Ptolemy's *Harmonies*—what I had promised my friends in the title of this book, which I named before I was sure of my discovery—what sixteen years ago I urged as a thing to be sought—that for which I joined Tycho Brahe, for which I settled in Prague, for which I have devoted the best part of my life to astronomical contemplation, at length I have brought to light and recognized its truth beyond my most sanguine expectations. It is not eighteen months since I got the first glimpse of light, three months since the dawn, very few days since the unveiled Sun, most admirable to gaze upon, burst upon me. . . . . For, after I had by unceasing toil through a long period of time, using the observations of Brahe, discovered the true distances of the orbits, at last, at last, the true relation of the periodic times to the orbits, and if you ask for the exact time,

. . though late, yet looked upon me idle
And after long time came;

conceived on the 8th of March of this year, 1618, but unsuccessfully brought to the test and for that reason rejected as false, but, finally returning on the 15th of May, by a new onset it overcame by storm the shadows of my mind, with such fullness of agreement between my seventeen-years' labor on the observations of Brahe and this present study of mine that I at first believed that I was dreaming and was assuming as an accepted principle what was still a subject of enquiry. But the principle is unquestionably true and quite exact: the periodic times of any two planets are to each other exactly as the cubes of the square roots of their median distances."

What an anti-climax it seems: the frenzy of a poet over a formal algebraic proposition. But we shall not understand Kepler unless

we realize that it was no anti-climax but the most glorious of culminations, beside which the rapture of a Keats over a nightingale is but a casual emotion. For this law, unlike the others, shows a relation not merely between the characteristics of a single planetary orbit, but between all the orbits of the solar system. For the first time in the history of the world it was seen that they were a system, and he, Joannes Kepler, was the first of mortal men to think again the thoughts of God at the creation.

" 'Nothing holds me,' he goes on, 'I will indulge my sacred fury; I will triumph over mankind by the honest confession that I have stolen the golden vases of the Egyptians to build up a tabernacle for my God far away from the confines of Egypt If you forgive me, I rejoice; if you are angry, I can bear it; the die is cast, the book is written, to be read either now or by posterity, I care not which; it may well wait a century for a reader as God has waited 6,000 years for an observer'."

How evasive is the line between genius and stupidity! Had Kepler failed, his name, if it had come down to us at all, would have become a symbol of the futility of arbitrary guessing. Wherein, then, lies his greatness?

I think it is in the steadfastness with which, in an age when fanciful speculation was still the dominant intellectual habit, he rejected one after another his fondest hopes because they could not be reconciled with the observations of Tycho Brahe. How easy it is for a theorist to ascribe apparent discrepancies in his work to errors of observation, even when the observations are his own, is well known to modern investigators. How much easier, then—almost overpoweringly so—must it have been in a speculative age, when the observations were those of another long dead and success was the passion of one's life. It is by his unswerving loyalty to truth that Kepler commands our homage, and not forgetting the daring imagination of Copernicus and the magnificent intellect of Galileo, we feel unable to quarrel with Brewster when he places Kepler next to Newton in the hierarchy of great men. His three laws of planetary motion have been the guidance of three centuries of research, and without them the great work of Newton would have been impossible, but it is the glory of Kepler that the man transcends the achievement. His work has brought him recognition, but it is he whom primarily we recognize.

A WINTER NIGHT

When I consider thy heavens, the work of thy *fingers*.—Psalm 8: 3.
His *arm* brought salvation.—Isaiah 59:16.

A moonless night in winter, on the plain,
  Has charms I cannot tell. O come and see
The great Creator's finger-work. I fain
  Would grasp the depth of man's iniquity:
It took His arm's full strength to rescue you and me.

The stars, like diamond facets, blaze above;
  The frosty snow-stars glitter bright below;
The Milky Way, a crown on Night's fair brow,
  Seems dimly to reflect the gleaming snow,
Which features jewelled wreaths when lightest zephyrs blow.

Aurora Borealis drapes the north
  In silken fabric, green and rose and blue;
The curtain stirs, as with a gentle breeze;
  A gay festoon of every rainbow hue
Recedes, then re-appears in colours strange and new.

A gentle swish pervades the frosty air,
  The rustling of the garments of the night,
As fairy hands rebuild the magic tent
  Of lavender and green on crystal bright,
With floating webs of rose, all fringed with silvery light.

We know Theee by Thy works, and by Thy Word,
  O great Creator of the Earth and Man!
We bow in reverence, and our souls are stirred
  When we behold the wonders of Thy plan,
Thou uncreated Cause, Who lived ere time began!

Winnipeg, Man. HANNAH M. SWEET.

ASTRONOMY THROUGH THE EYES OF THE ANCIENTS

By Una C. Taylor

IN this truly scientific age, when astronomers can not only measure the distance to the stars but can weigh suns a thousand times as large as our own and a million times as far away, we are apt to forget the fantastic conceptions which the ancients held regarding the universe. In the distant past, except among the Greeks and Egyptians, all star lore was an essential part of religion and it remained so until the candle of astronomy was lighted. The temples of the ancients were observatories, a relic of which is the crescent that adorns the mosques of the Mohammedans, for both the Turk and Arab once worshipped the moon as a divinity. Many religious scholars now believe that the Tower of Babel was such a temple observatory. Light and darkness were symbolic of good and evil and in all cuneiform and hieroglyphic languages the sign for God was a star.

Thus, from remotest antiquity primitive peoples have looked with awe upon the stars. They were regarded as the abode of the blest and worshipped as divine guardians. The early Hebrew believed the sun and the moon and the stars danced forever before Adam in Paradise. The Maories of New Zealand thought the stars to be the souls of heroes, their brightness depending upon the number of victims slain in battle; some Asiatic tribes believed the stars to be the children of the sun and the moon. The Chaldeans thought the stars to be little lamps suspended by strings and managed by the angels. Even in 350 B.C. Xenophanes taught that the stars were lighted each evening and blown out in the morning by the gods. The Iberians (early race in Spain) believed the stars to be golden nail-heads holding up the ceiling of the universe. Even Homer firmly believed that the stars were carried across the sky in chariots. The Jesuit Riccioli thought that the stars were rolled along by angels. (Fancy an angel trying to roll Neptune around the sun, or, more ludicrous still, one of our large suns that travel at the rate of seventeen million miles a day.) Certain African tribes believed that the sun and moon were mortals and once lived here upon earth. The Egyptians had a similar belief

for they worshipped Osiris as a Sun-god and Isis as a Moon-god; and while showing Plutarch the graves of these Deities they at the same time pointed to the stars they had been metamorphosed into in the heavens. The Druids were so convinced of life on the stars that they often loaned money on the security that it be repaid when they met after death on a certain star. They even enclosed in the bier letters of introduction to friends gone before. Then, too, there is a very old legend that tells us there were no stars in the skies until the giants had a quarrel with the sun and the moon and began throwing stones at them, thus making holes in the blue vault of heaven.

Certain Indian tribes believed the moon to be a dish of nectar, which, when it waned, was either supped or tipped over by the gods. The very early Danes thought the moon to be made of cheese from the milk of the Milky Way. The Milky Way itself came in for much absurd conjecture. The Greeks regarded it as a clumsy join in the heavens, thus letting through some of the light that was then supposed to exist everywhere beyond the solid sky. However, the general belief among the ancients was that it was a pathway leading to the land of hereafter. Algonquin Indians spoke of it as the camp-fires along the road of souls on their way to the happy hunting grounds. Both the Basques and early French firmly believed the Milky Way to be lamps held by angels to show mortals the way to heaven.

Whole volumes could be written on the abject fear and dread that all primitive races had of an eclipse. They thought it was then that the moon had been bewitched, and even today there are tribes in Africa who think that when the world has been darkened by the moon creeping over the face of the sun that the sun has been swallowed by a dragon.

Down the ages comets have been regarded as a sign of coming disaster—war, famine and pestilence. To them a comet was a flaming sword brandished by an angry god threatening vengeance. In 1456, Halley's comet so terrified the world that the Pope ordered bells on all the churches to be rung so that the populace might join in special prayer for protection. It has been said that the hens in Rome were so frightened that there were pictures of a comet on the eggs. I will not vouch for this. It is interesting to know

that 226 years later a young professor of Oxford applied Newton's law of gravitation and other celestial dynamics to this comet and predicted its return in the year 1758, 75 years later. He was subject to much ridicule for up to that time no one ever thought that a comet travelled a regular path. True enough, on Christmas day of that year the comet returned to shine on Halley s grave, and bore mute testimony of the might of human thought in wresting so profound a secret from the universe.

Plutarch tells us that the Druid priests taught that hurricanes and tempests were due to the death of some great man; their soul in departing caused a vacuum. There is in the library at Turin a curious chart of the ninth century showing on four sides of the earth the figure of a horse standing on a bellows representing wind.

The great Diogenes was condemned to death for teaching that the sun was really bigger than it looked. Pericles defended him so ably that he escaped death but was sent into exile.

Sun worship was prevalent among primitive races and even today we have considerable sympathy with such a rite. Sun rooms; sun bath medical treatment. Without the sun our earth, if indeed there could be any earth at all, would be a cold misty planet revolving in space; no life of any kind, not even a blade of grass. Without the sun neither you nor I nor any of our ancestors would ever have seen the light of day. The difference between our conception of the sun and that of the ancients is that they worshipped the sun as a divine being while we regard it as an emanation of a divine being. There is a beautiful old hymn in Sanskrit, which was chanted by the sun-worshippers thousands of years ago——

> Yesterday is only a dream,
> Tomorrow is but a vision,
> But Today *well-lived* makes
> Every Yesterday a dream of happiness,
> Every Tomorrow a vision of hope.
> Look well, therefore, to *this Day;*
> Such is the Salutation of the Dawn.

We can almost picture those old Hindu and Persian worshippers arrayed in their long flowing robes, bowing and chanting this verse to the rising sun. It is a logic worthy of present day practice.

The ancients had some very remarkable theories to explain how

the sun set in the west and rose again in the east when the earth was a flat plain with a solid dome above. One theory was that when the sun disappeared at sunset it fell into the ocean and was drowned and the gods had to work all night long making a new sun. The Iberians actually imagined that they heard the hissing of the water when this red-hot globe plunged therein. It is recorded that Brutus was about to conquer Spain when this terrific noise scared him nearly to death and he fled, taking his troops with him. As Sir Robert Ball remarks, "this was thought to be too great a waste of perfectly good suns", so they devised a new theory. This was that when the sun disappeared on the western horizon it was caught in the arms of the god Vulcan who was waiting to receive it. He carefully bestowed it in his boat and all night long he rowed around by the north, arriving in the east just before dawn, and with one titanic effort he hoisted it over the mountains to begin another day's journey across the sky.

The Egyptians believed the sun was daily rowed across the sky in a boat. Another explanation was that the sun committed suicide each evening and the red colours at sunset were said to be the blood flowing from his wound.

All down the ages there has been much weird speculation regarding our earth. The early Hindoos thought it to be hemispherical, an inverted bowl as it were, resting on the back of four elephants and the elephants were supposed to be standing on the back of an enormous turtle. This may have been symbolic, the elephants representing the four points of the compass and the turtle eternity.

Plato believed the earth to be a perfect cube, with Athens in the centre.

The Arabs of 11th century thought the earth to be egg-shaped, floating upright, with Jerusalem at the top.

The world according to Cosmas was a large oblong box, patterned after the Tabernacle that Moses erected in the desert, from which flowed four rivers into Paradise.

Homer's conception was that portion of Southern Europe, Eastern Asia and Africa from Thebes northward which encircled the Mediterranean Sea, around all this flowed the River Ocean.

He marked the entrance to the infernal regions in the vicinity of what is now Germany.

Even Columbus believed the earth to be pear-shaped, and after his third trip claimed the River Orinoco to be one of the rivers that flowed into Paradise.

Dante based his Divine Comedy on the theory of Copernicus, and although it is only 265 years since Milton wrote Paradise Lost, and no doubt he made use of the most advanced science of his time to stimulate his imagination, yet his universe compares to ours only as a drop of water to the ocean. All out of doors was a vile heresy, even the air breathed was full of demons and monsters of iniquity, and remained so until January 7, 1610, when Galileo turned a telescope on the heavens. At that moment flocks of fallacies and absurd conceptions disappeared into thin air. The veil of ignorance had been rent. Crude error was gone, and the works of creation shone forth in their own true light.

These are but a few of the early beliefs that have come down to us from antiquity.

Where astronomy had its birth is a much disputed question, but authorities now fairly agree that it was somewhere in the vicinity of Mount Ararat. It was safe to assume that it was not in India, as the elephant, tiger and monkey are missing among the constellations; nor in Arabia nor Egypt, for neither the crocodile nor camel is represented; and Greece, Italy and Spain are excluded by reason of the fact that the lion is so prominent a stellar figure. That leaves us that part of the world bounded by the Mediterranean, Aegean, Black and Caspian Seas.

The Chaldeans, Egyptians and Chinese were among the earliest watchers of the heavens. We can go back into Egypt for a period of more than six or seven thousand years to monuments on which are inscribed astronomical information; everything connected with dawn and sunrise was worshipped by the Egyptians. The names of star and solar temples are legion and some, it is believed, were oriented to the rising or setting of the sun at the winter or summer solstice. This is also seen in Stonehenge, in England. The priests were well versed in star lore, and to these temple observatories journeyed Aristotle and other Greek philosophers, that they might drink at the fount of their knowledge. There are seven Egyptian

temples so arranged that the beams of the bright star Sirius in its rising and setting shone on the inner altar, the holy of holies. This brightest of all our stars was worshipped in the valley of the Nile long before Rome had been heard of; also the blazing star of the Masonic emblem had its origin in this star.

The Babylonian tablets carry us into the dim past more than five thousand years and reveal to us the fact that a race called Acadians came down into Chaldea from the mountains of Elam and brought with them the sphere and the zodiac, and the astonishing part of it is that this zodiac brought to Babylonia five thousand years ago is almost the same as we have today.

In Chinese history we read that the Emperor Chung Kang of the great Hia Dynasty in the year 2147 B.C. had his court astronomer beheaded because he failed to correctly predict the coming of an eclipse. Also the Vedas, the sacred literature of the Hindus, written some 3,500 years ago, vibrate with adoration for the sun, moon and stars. Moreover, it is a well-known fact that more than 3000 years ago the Persians divided the heavens into four great districts, each being watched over by one of the royal stars,—Aldebaran, Antares, Regulus and Fomalhaut.

There are many traditions respecting the origin of star lore, one of the most interesting being that the immediate sons of Adam were so well versed that Seth and Enoch inscribed upon two pillars, one of stone and one of brick, not only the signs of the zodiac but the names and virtues of many stars. Josephus, the great Jewish historian, claims he saw one of these with the serpent, an emblem of revolution, entwined and some even connect this with our dollar sign today.

The oldest mention of names of the constellations, other than those of the zodiac, is in Hesiod, who lived about 900 B.C., in his "Works and Days" where he gives the names of the Pleiades, Orion, Arcturus, and Sirius. These are referred to in the Book of Job and Homer too sang of them. I might say that Hesiod's conception of the universe was a bit cramped, for he claimed that it took Vulcan's anvil seven days to fall from furthermost heaven to the earth. Today we know that it would take a non-stop aeroplane twenty million years to go to the *nearest* star We are well aware that from farthest antiquity there comes a wealth of

sky lore in the mythology that is entwined among the constellations, but time will permit me to mention but one, Ursa Major, the Bear, a portion of which is the familiar Big Dipper. Just why this group of stars should be called the Bear by peoples of every clime from far north Finland to the Valley of the Euphrates and even in India, is perplexing, for the arrangement of these stars in no way suggests a bear, or indeed any other animal. Aristotle claimed it was The non-Christian Arabs named it the Great Coffin owing to its slow motion, the tail being the mourners. The Christian Arabs made it the grave of Lazarus, the three stars in the tail being the weepers, Mary, Martha and a hand-maiden.

From time immemorial astrology has flourished, and the character, position and movements of mankind, in fact their whole life history, was directed by heavenly bodies; but it received a severe jolt when Copernicus established the fact (although not generally accepted until after his death) that the earth itself was one of the planetary bodies. It is interesting to know that even in the time of Kepler astrology was more thought of than astronomy, for while Kepler was one of our great astronomers he could not live by that alone and so made star charts for astrologers to add to his meagre salary. Dean Swift dealt it a death blow in England.

Mythology hung ripe upon the bough of Greek thought until about the sixth century B.C. The heavens were peopled with malicious powers until Thales, one of the seven wise men of Greece, saw a glimmering of the true universe. He claimed everything developed from one source or cauldron. Heretofore there was no systematic order. Heroes were translated to the sky; became stars and ruled the people on earth. Thales declared that stars belonged in the sky and heroes on earth. He was the first man in the western world to predict an eclipse, although the Chinese had done so some fifteen hundred years before this.

Four hundred years later another great mind took up the study of the heavens. This was the great Hipparchus, the father of astronomy. He was born about 150 B.C. He made a catalogue of 1,080 stars, determined the length of the year, and made many important discoveries.

One hundred and fifty years after the birth of Christ another

great astronomer arose, Ptolemy. He mapped the course of the planets in the heavens, and while it was a creditable feat, it is just a question if he did not do more harm than good by leading the world to believe that our earth was the centre of the universe, solid and immovable, around which the sun and planets revolved on crystal spheres. I might say that it was the early church fathers who added these spheres. Absurd as it seems to us it was the belief of the learned for more than thirteen hundred years; until even after Columbus discovered America.

We have seen that for centuries before the coming of Christ both the Greeks and the Chaldeans had garnered considerable knowledge of the universe about them, but this was all snuffed out, due partly to the Dark Ages and partly to the opposition of the early church towards any new thought. Thus until well into the sixteenth century our earth remained the centre of creation and around it revolved spheres of crystal, each one bearing a planet or the stars.

It is to be deplored that this early church was so averse to the findings of science. It is only a little over three hundred years ago that Bruno was burnt and his ashes thrown to the four winds for daring to teach that the earth travelled around the sun. Galileo almost suffered the same fate. These church fathers bitterly denounced the theory of the earth being a sphere, and the view that it was inhabited at the antipodes was rank heresy. "It was contrary to the Scriptures, ' argued Augustine, "for God would not create a people who could not trace their descent directly from Adam, and anyway, how could men live standing on their heads?"

Saint Vincent Ferrier taught that the age of the earth must correspond in years to the number of verses in the Psalms, 2,537. We are informed today that the earth is at least three thousand million years old.

Father Hourdain claimed that if the earth did rotate on its axis, it was caused by the souls of the damned clinging to the walls and ceiling of hell in their frantic efforts to escape the fiery flames, thus starting the world turning like a squirrel in a cage.

The God of Bethel is not the God we know today. God's universe at the time of Abraham, Jacob and Isaac was a flat, square plane; the sky was a solid dome and the stars were little lights

lighted and blown out by the angels. Below this were the fiery caverns of hell, created expressly by a vengeful God in which sinners or even those who could not accept certain church doctrines sizzled forever in agony.

Contrast this with the conception of the universe that science gives to the world today. In reality fathomless space seems filled with luminous dust, every grain of which is a stupendous sun travelling at a terrific rate of speed.

The diameter of our universe is eighteen hundred thousand billions of miles. (It would take a non-stop aeroplane travelling at the rate of 125 miles an hour one billion, four hundred and forty thousand million years to cross it), and yet the photographic plate on our great telescopes proves that there are at least two million such other universes. Light travels from London and Australia in one-fifteenth of a second. It seems like a fairy tale that an astronomer can stand on our earth and take the picture of other universes, or galaxies, so far away that it takes light anywhere from one million to one hundred and forty-six million years to come to us. Each year new vistas will be opened up and new universes will appear. What will the picture be a thousand years from now?

The God that dwells in the Temple of Astronomy is a God who has created not only our own universe whose immensity we cannot grasp, but millions of such universes and has sent them spinning with perfect harmony through everlasting time and space.

Winnipeg, Man.

REFINING PLUTO'S ORBIT*

By Henry Norris Russell

PLUTO continues to figure in the astronomical news, and with good reason. By the generosity of Dr. S. B. Nicholson of the Mount Wilson Observatory, the writer is permitted the privilege of telling here of some of his results, prepared for presentation at the scientific meetings held during the Christmas holidays. Dr. Nicholson, the discoverer of the ninth satellite of Jupiter, and Mr. Mayall have been at work upon Pluto since its discovery was announced. They discovered the faint images of the planet on the plates taken in 1919, which have been of so much importance in determining its orbit, and computed the first accurate orbit from these.

Now, utilizing the numerous observations of the spring and autumn of 1930 and the pre-discovery photographic positions of 1927, 1921, and 1919, they have completed a very accurate calculation which should leave but a small margin of oustanding uncertainty. These agree so closely with the elements derived by Bower and Whipple at Berkeley, which form the basis of the previous article on Pluto,† that the differences would be practically imperceptible in the diagrams which were there given. Small as the differences are, however, they are interesting, for they illustrate still more of the rather entertaining complications which the calculator has to face.

The planets as well as the sun are attracting Pluto. In preliminary computations for this or any other planet this influence is simply ignored, but enough is known about the planet's motion now to justify and indeed to demand some better procedure. There are, however, several ways of doing this. In the first place, since all the planets are inside Pluto's orbit, they are attracting it roughly in the same direction as the sun and we may take account of this

*This article is printed in *Scientific American* for February. Advance proofs of the article were very kindly furnished by the Astronomical Editor of that magazine.—Editor.

†See the last number of this Journal.—Editor.

roughly by assuming that they are all lumped with the sun itself, adding their masses to the sun's. This is what Bower and Whipple did and it was altogether the correct procedure at that stage of the work when the real period and the form of the orbit were still considerably uncertain.

After a good first orbit was available the way was open to calculate by well-known though laborious methods just what the attraction of the planets upon Pluto was year by year and how much it altered the planet's motion. But here we must ask a new question. What do we mean by the "unaltered" motion? Pluto has never moved in an "unaltered" orbit and to define one we must get rid of the other planets and their action by some imaginary process and then calculate how much the planet's position in its real orbit differed from that which it would have had under the simpler conditions which we have invented.

The standard way of doing this is to suppose that at a given instant all the planets were annihilated, leaving Pluto and the sun alone in the system but with exactly the same mutual distance and relative motion. After this imaginary catastrophe Pluto's orbit would be an exact and unchangeable ellipse and its motion could be easily computed. With this as a standard it is then possible to work out just how far the real planet will deviate at any other time from the position which it would have had under the fictitious but simply calculable conditions. At the moment of our suppositious change the position and velocity of the planet is exactly the same in the two systems, hence the real and artificially simplified orbit run very close together in the neighbourhood of this time—which, by the way, is called the "epoch of osculation" (the word is borrowed from the mathematicians, who have long employed it to describe a close type of contact between two curves!)

But other simplifications of the solar system can be imagined. For example one might suppose that at a given instant the planets were not annihilated but were combined with the sun into a single mass. The best point at which to put this mass is obviously at the centre of gravity of the whole system and not the one where the sun's centre happens to be. Taking the surviving planet's motion about the new increased attracting mass, we derive another idealized orbit known as the "barycentric" orbit (about the centre of gravity)

instead of the previous heliocentric orbit (about the sun as attracting centre.)

Each of these processes is mathematically quite legitimate, provided that it is clearly explained just what hypothesis has been adopted. But the two orbits will never agree, for the central attracting mass differs and so does the planet's position and motion at the given time. Which one will give the better idea of the planet's subsequent motion? This depends on where the planet is in the solar system. For the earth, or for an asteroid like Eros whose orbit lies far inside those of Jupiter and Saturn, the heliocentric orbit will evidently be the best, because these planets tend on the average, though not always, to pull the asteroid away from the sun and their influence could be better represented by diminishing the sun's mass than by increasing it. But for Pluto the reverse is the case and the barycentric orbit is to be preferred.

The differences between the two are far from negligible, the greatest discrepancy being in the period, for which Nicholson and Mayall find 249.20 years in the heliocentric orbit and 247.69 in the barycentric. These differ by one part in 164—a surprisingly large amount at first sight. The perplexity grows when one realizes that by Kepler's laws an increase in the attracting mass of 1 per cent. will, other things being equal, decrease the period by 1/2 of 1 per cent. The combined mass of the planets is about 1/700th that of the sun and we should therefore expect the barycentric period to be shorter by 1/1400th part, or two months instead of 18.

But the principal difference between our two hypotheses is not that we have altered the *magnitude* of the attracting mass but that we have changed its *motion*. At the epoch of osculation of the orbit (1930) Jupiter was almost in line between Pluto and the sun. It was moving in the same direction as Pluto (Figure 1) while the sun, which lies on the opposite side of the centre of gravity C, must therefore have been moving in the opposite direction. The motion of Pluto relative to the sun was therefore more rapid than its motion relative to the centre of gravity. Now a more rapid motion at a given point in the orbit implies a larger orbit—so much so that it takes longer than before to make the whole circuit. Hence the heliocentric period should be the longer. We can easily figure out how much. The average orbital velocity of Jupiter is 2.76 times

more rapid than Pluto's, the sun is 1047 times more massive than Jupiter, and so its velocity about the centre of gravity is proportionately slower or 1/380th of Pluto's. Hence the change in our scheme of reference speeds up Pluto by one part in 380.

Now it follows from Kepler's laws that an increase in orbital speed by 1 per cent. (in a nearly circular orbit) will increase the period by 3 per cent. Hence we should expect the heliocentric

FIG. 1.

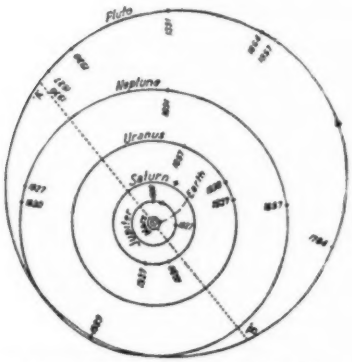

FIG. 2.—Pluto's orbit drawn to scale with the orbits of the other planets. Reproduced from Leaflet 30 of the Astronomical Society of the Pacific by Dr. F. C. Leonard, this drawing was adapted from a diagram made by Mr. F. L. Whipple. Since it was issued in August, it was based on earlier data than the author's diagrams and differs very slightly.

period of Pluto to be longer than the other by 3/380ths of its amount, or 1.96 years. This is almost six months more than the actual computations give.

But we have so far taken account only of the influence of Jupiter. Saturn in 1930 was on the opposite side of the sun and acted in the opposite direction and almost to the maximum possible amount. Owing to its smaller mass and lower orbital velocity, its effect is only 22 per cent. of Jupiter's, and in this case decreases the helio-

centric period by 0.44 year. The combined effect is an increase by 1.55 years or, allowing also for the change in the assumed mass, 1.72 years. The difference given by the precise calculations is 1.51 years. It is by no means usual to find a case in which such elementary calculation gives so good an approximation.

From what has been said it is clear that if the true orbit of Pluto about the centre of gravity of the solar system did not change at all, the orbit calculated by considering the sun alone would sometimes come out with a period more than two years too long and again as much too short.

Even the barycentric orbit is not free from variations. The attraction of the planets and especially of Neptune, which has been fairly near Pluto during the last century, will alter it considerably—though by much less than the amounts just considered. It is possible by much more extensive calculations to get rid of these changes also, and to find a "mean orbit" which gives the true mean value of the period, but the time for this has not yet arrived.

Meanwhile we may note that with the new period of 247.69 years, which should be much nearer the truth than any previous value, is also much nearer to being 1 1/2 times Neptune's period of 164.77 years. After three revolutions of Neptune and two of Pluto, the former is only one year's motion ahead instead of four. The interval between the close approaches of the two planets is therefore about four times as long as was previously estimated and probably exceeds 40,000 years, while the last such conjunction happened more than 10,000 years ago.

Of wider interest than these calculations is another result which Nicholson and Mayall have reached. They have made the first determination of the mass of Pluto. From the observations of Neptune, proceeding in the usual way, they find that definite evidence of the influence of Pluto's attraction is present, and that its mass is comparable with that of the earth. There is a continuous series of observations of Neptune from the discovery in 1846 to 1930, and two isolated observations in 1795 by Lalande who recorded the planet's position while observing the places of faint stars and supposed it to be only one more of the thousands which he had measured. Observing methods were less precise in those days and this position is less accurate than the others. If it is included in the

solution the mass of Pluto comes out 1.08 ± 0.23 times the earth's. If it is excluded, the remaining observations give the value 0.72 ± 0.05. The remarkable diminution in the probable error for the second result shows that the later observations are much better represented if the early one is disregarded. Whether so drastic a course is justified cannot be settled till we have a decade or two more of observation or until the perturbations of Uranus by Pluto have been worked up. In any case it is clear that the new planet has a considerable mass and is capable of producing easily perceptible influences on the others by its attraction.

With the mass it is probable that its diameter is not very different from the earth's. If so, its apparent disk should be less than $0''.5$ in diameter. To detect this in so faint an object would tax the powers of the greatest telescopes and demand the very best conditions of seeing which have not yet apparently been available.

The planet's faintness, too, is no longer seriously puzzling. Pluto reflects a little more light than Mars would do in his place. If his diameter equals the earth's his albedo would be one-third that of Mars. This is two-fifths the average value for the moon, or about equal to that of the moon's darker area

So all contradictions vanish and we may welcome Pluto to a fully accredited place among the major planets of our system.

THE ORIGIN OF THE SURFACE FEATURES OF THE MOON*

By A. C. GIFFORD

ALTHOUGH we can never handle or place under a microscope any rock-specimens from the moon, and though we can never climb down the precipitous slopes of its giant rings, our satellite is far from being without interest to the physicist and the geologist. Its scenery differs essentially from that of every terrestrial type, and is indeed absolutely unique amongst all that we can see in the universe.

But whilst all the conditions on the lunar surface differ so widely from those experienced here, chemical and physical principles are identically the same, and it should be possible to infer correctly the origin of the forms observed. A telescope magnifying 2,000 diameters brings the moon apparently within 120 miles of us, and, as each feature is presented under a series of different illuminations during every month, it is possible to get an accurate knowledge of the vertical relief. The moon being practically destitute of atmosphere, our view is never broken by lunar clouds or cloud shadows. The sun shines on the lunar rocks with unmitigated intensity for a fortnight at a time, and then leaves them to cold and darkness for a similar period. Even the want of a telescope is no longer a bar to successful study of the moon. Owing to the marvellous advance of photography this can be carried out at the study-table or in an armchair by the fire. Excellent pictures have been made of all the details of the lunar surface under every phase. The whole of the face which the moon turns towards us is better known than many parts of our own globe. We can tell the height of each peak, the depth of each valley, and the diameter of each crater. But whilst selenography is in an advanced state, selenology has quite failed to make any similar progress. The explanations of the origin of lunar forms are unsatisfying if not absolutely unscientific. No agreement has been reached amongst astronomers about a single one.

A glance at the full moon with the naked eye, or the inspection of a photograph of it, shows at once that some parts of the surface

*From the *New Zealand Journal of Science and Technology*, pp. 319-27, 1930.

are much brighter than others. The dark areas cover between one-third and one-half of the visible surface, and form a design like a charcoal drawing on a light ground. This design is executed in a very broad style, but is certainly not that of a cubist, for the strokes, instead of being square, appear to be circular or elliptical. The dark markings, which are still called "seas," though there is probably not a drop of water in any one of them, range in size from Mare Imbrium (750 miles in diameter) to Mare Crisium (less than half that width). Their grouping suggests many weird forms besides that of the traditional man in the moon. A glance through a telescope shows that the lunar surface, especially that of the bright areas, is full of detail, every increase of magnification revealing still more. The lunar markings thus afford us a good test for telescopic power as those of a diatom do for that of a microscope. But however minutely the surface is examined, the circle still forms the basis of the whole design. Circular forms, fore-shortened to ellipses near the margin, are found everywhere, and range in size from the minutest pits disclosed by the largest telescope to the immense dark regions called "seas." Nor is this all. The lunar surface appears to be a palimpsest from which innumerable ancient writings have been imperfectly removed. Traces of ruined or partly obliterated rings may be discerned nearly everywhere. When these ancient records are taken into account the ring formations appear to be sufficiently numerous and extensive to cover practically the whole of the surface. They seem to be scattered indiscriminately. One ring often overlaps another, and smaller ones are found inside, outside, and even on the very rims of the larger ones. The series of sizes is almost complete from the smallest pit to the largest sea. The forms intermediate in size between the largest pits and the smallest seas are called craters, mountain-rings, or walled plains.

The Vertical Relief

The vertical relief is thoroughly characteristic. The floor of each ring is much lower, and the rim considerably higher, than the level of the surrounding plain. When a crater has a central peak it does not rise nearly to the level of the mountain ring. A lunar crater is clearly not a mountain: it is essentially a saucer-shaped depression, with an elevated rim.

The Seas

The dark areas are much smoother than the rest of the lunar surface. Within them craters are much fewer than in other parts. Those that are so situated fall into two sharply-defined classes: some are in almost perfect preservation, others are almost obliterated; there are practically no intermediate forms. It looks as if at some particular epoch all the older features throughout these regions had been smoothed or washed away, and a fresh surface prepared to inaugurate a new era in the building of lunar scenery. The smoothing of these dark areas seems to have been accompanied by a lowering of the surface, partly balanced in some cases by the formation of a high encircling mountain wall. A magnificent example of this is afforded by Mare Imbrium, whose boundary is made up in part of the grand chains of the lunar Apennines, the Caucasus, and the Alps.

There is thus a good deal in common between the seas, the craters, and the pits. They all share the circularity of outline, the depressed floor, and the elevated rim.

The Origin

The problem of the origin of the lunar formations has attracted attention for more than two hundred and sixty years. From time to time many explanations have been suggested, some more fantastic than others, but all inadequate. So much was this the case that it became customary for astronomers to acknowledge that we do not know in the least how these marvellous forms were produced. A summary of the most important hypotheses was given in the *New Zealand Journal of Science and Technology* in September, 1924. It was then shown that nearly every theory is open to some insuperable objection. It is not even a case in which there can be an element of truth in several rival theories. Most of these are mutually exclusive. If, for instance, the surface was, as one theorist maintains, a vast sheet of ice, the rings clearly could not be, as another affirms, huge growths of coral. Fortunately, theories such as these are no longer regarded seriously. Nevertheless sharp differences of opinion still exist. Many astronomers still regard the origin as

quite unknown. Of those who believe that the question can be solved, some think that the ring formations are due to internal forces, others attribute them to action from without. Fortunately it is possible to apply numerical and other crucial tests, which should enable us to decide which of these views is in all probability the true one. This was attempted in the article already referred to. Reasons were given for considering all previous theories untenable, but a modification of the meteoric one was suggested which seems to account reasonably and satisfactorily for the observed facts. No objections which appear valid have as yet been raised against this theory, and recent studies have increased the probability of its truth.

Further consideration and discussion, however, are urgently required, for, in spite of all the unanswered objections to it, the classical volcanic theory is still very generally accepted. Since the New Year two new astronomical works have reached Wellington. One of these comes from America, and is devoted entirely to the moon. In it the volcanic theory is adopted without any critical examination. The other, from Cambridge University Observatory, deals with the sun, the stars, and the universe. One page is given to the origin of the crater formations on the moon. The volcanic and the meteoric hypotheses are discussed, and it is definitely stated that neither theory is satisfactory. It is evident, however, that the new form of the meteoric theory has not been examined by the author.

Objection to the Volcanic Theory

The use of the term "crater" in describing lunar rings appears to be the origin of the volcanic theory. Since multitudes of craters are found on its surface, it is inferred that the moon must at some time in the past have been a veritable volcanic inferno.

But the characteristic form of the lunar rings, their astounding number, their peculiar distribution, and their great range in size all tell strongly against the volcanic theory, as does also the absence of water on the moon.

The Form of a Typical Lunar Crater

As long ago as 1892 Gilbert showed how completely a terrestrial volcano differs from a lunar ring. The latter is essentially a hollow rather than a mountain. Its floor is considerably lower than the surface of the surrounding plain. The material which forms its mountain-rim is insufficient to fill the cavity. Its central peak, if it has one, does not rise to the level of the ring-wall, and is comparatively insignificant in its dimensions.

Every lunar crater appears, moreover, to be the result of one single explosive action which hollowed out the great saucer-shaped depression and built most of the ejected material into the mountain-rim. Terrestrial volcanoes are built up by intermittent action. This is inconceivable in the case of a lunar ring, for the material thrown out in different eruptions would not all be sent exactly the same distance. There is not a single instance of a lunar crater left half-finished, though there are innumerable ones half-destroyed.

The central peak affords further conclusive evidence. According to the explosive meteoric theory it is formed quite naturally at the same time as the ring. According to the volcanic theory there were in every case not more than two outbursts. The second, when it occurred, was quite different in character from the first. The original eruption made a vast hollow surrounded by a circular wall; the second made a comparatively insignificant mountain peak. There is no instance of any connecting-link between these utterly distinct types of eruption. According to the new meteoric hypothesis, the complete form, with its saucer-shaped depression, mountain-ring, and central peak, was produced by a single explosion, and the configuration can be predicted mathematically. Observation shows that the typical form is exactly as theory demands. The proof of this fact is given in the article already referred to.

The Great Number of Craters

Except in the so-called seas, the craters, and the ruins of older ones, cover almost the whole surface. It seems incredible that volcanic action could ever have been so intense and so universal.

Their distribution: Lunar craters are distributed indiscrim-

inately over the surface. There is no indication of their following lines of weakness, as terrestrial volcanoes do. Craters are found within and on the sides of others, sometimes perched on their very rims, in positions that would be most unlikely for the occurrence of secondary volcanic outbursts.

Their size: The rings range in size from the tiniest pits discernible with the 100-in. telescope up to immense structures like Grimaldi and Clavius, about 150 miles in diameter. But we can hardly stop even here, for the lunar seas carry on the series up to Mare Imbrium, 750 miles across. The forms are so simple that it is reasonable to attribute them all to the same type of action; and volcanic action certainly does not meet the case.

Absence of Water

Steam plays such a prominent part in terrestrial volcanic action that the absence of water on the moon affords another objection to the volcanic theory. No one has explained how volcanic action on the moon could be so violently explosive in character without the help of water. Nasmyth and Carpenter attribute the force to the expansion of liquid rock during solidification. But surely this would be a gradual, not an explosive process. It would hardly throw mountainous quantities of rock to distances of sixty or seventy miles. The theory also fails to explain why lunar craters are essentially hollows rather than elevations.

Early Forms of the Meteoric Theory

In all the early forms of the meteoric theory the meteorites were supposed to have fallen whilst the surface was still in a plastic state. They were believed also to have dropped almost vertically on to this surface, and to have made the indentation and the surrounding wall by their impact and the resulting splash. It was even suggested that the central peak might be a remnant of the enormous meteorite itself. To such theories three main objections were urged:—

(1) The meteors must have been far more numerous and far more gigantic than appears likely.

(2) If such a bombardment of the moon ever took place, the earth should show similar scars.

(3) It is extremely improbable that the meteoric downpour could have fallen vertically. The majority of impacts must have been oblique.

It was comparatively easy to find reasonable answers to the first two of these objections, but the third proved to be absolutely insuperable, and thus the meteoric hypothesis came to be discredited.

The New Meteoric Hypothesis

But one most important fact had not been taken into account. A meteorite moving at a speed of many miles a second has a store of kinetic energy which renders it, when suddenly stopped, an explosive of unparalleled violence. The earliest publication of this fact that I have noticed is a statement made by Professor A. W. Bickerton at a meeting of the British Astronomical Association in 1915. He pointed out that normal meteoric speed is sufficient to produce explosive action, and that consequently oblique impact is able to produce roughly circular rings. A moment's calculation is enough to verify this. An express train running sixty miles an hour has energy equivalent only to about one-twelfth of a calorie per gram. A meteorite flying one mile per second has 3,600 times as much. But meteorites are known to meet the earth's atmosphere with far higher speeds than this, usually ranging, in fact, from eight to forty-five miles a second. Now, if the speed is forty miles per second, the energy has the enormous value of 494,700 calories per gram—over four hundred times the energy of dynamite. Many meteorites must have struck the moon with speeds even greater than forty miles a second.

It is estimated that twenty million meteors enter the earth's atmosphere every day. Also, ever since the formation of the solar system, the sun, every planet, and every satellite has been gathering up meteoric matter. Since, after so many million years, the gleanings are still so great, the meteoric harvests of the early days must have been colossal. Probably all the larger masses, with very eccentric orbits, were gathered up fairly soon in the life-history of the system, and only small survivors, whose orbits are easily perturbed, are now being drawn into the net.

The Collision of a Meteorite with the Moon

Let us picture now what must happen when a massive meteorite strikes the surface of the moon with a high velocity. The moon has less than one-eightieth of the mass of the earth, and considerably less than two-thirds of its density. Gravitation at its surface, therefore, is less than one-sixth of what it is here. In consequence the materials of the lunar surface are likely to be far less consolidated than terrestrial rocks. We shall see reasons later for believing also that they are distinctly fragmentary. There is neither wind, nor water, nor ice to cause any subaerial or subaqueous denudation. No percolation of liquids carries chemicals to cement the rocks. The meteorite, in its headlong flight, finds no air to obstruct its onward motion. Its speed is slightly increased by the attraction of the moon, but this effect is insignificant in comparison with that due to the sun, and to the speed of the earth and moon in their orbits.

A body drawn towards the sun from an immense distance will have, when it reaches the earth's orbit, a speed of about twenty-six miles a second. It may either meet or overtake the earth or the moon; and to find the resultant relative velocity all the separate velocities must be combined according to the parallelogram law. The resultant, as we have seen, usually ranges between eight and forty-five miles a second.

Meeting the loose material of the moon, a meteorite, striking at such a speed, must penetrate some distance before it is stopped. If, for example, a speed of forty miles a second is destroyed by a uniform resistance in one-tenth of a second, the meteorite will penetrate to a distance of about two miles. In that tenth of a second its kinetic energy of translation is transformed into molecular or atomic agitation. The energy required to vaporize the entire meteorite is a negligible fraction of that which it possesses, being in fact only a thousand or so calories out of half a million. After vaporizing the meteorite the surplus energy is still over four hundred times the energy of dynamite, and the resulting explosion must be correspondingly intense.

A strange want of appreciation of the magnitude of a meteorite's store of energy is shown in most astronomical books, and even in

Professor Smart's new work already referred to, after saying that there is no *a priori* reason why meteors should fall vertically, he adds: "But this objection becomes invalid if the crater is supposed to be the result of a meteor imbedding itself in the almost solid lunar crust, the *friction*, as before, vaporizing *at least the outer parts* of the meteor, upon which follows a shattering explosion." He goes on to say that the meteorites must have been enormous, comparable in size with the minor planets.

The Result of the Explosion

If an explosion of such stupendous intensity takes place a mile or two below the surface of the moon, what must be the result? Clearly there is no time for conduction of heat, or for any considerable amount of melting. Surrounding materials will be instantaneously shattered or pulverized by the shock. Those below will be violently compressed, those around and above will be ejected. A vast saucer-shaped depression will be suddenly formed, and the space above it will be filled with flying fragments.

It is an interesting little problem to determine the form of the resulting structure when all this material is drawn back by gravitation. To take an ideal case: Suppose material to be ejected from a point on a horizontal plane and projected with a definite velocity and distributed equally in all directions in the space above the plane, and suppose all this material to rest where it falls. It is easy to calculate the relative density at any distance from the point. The result is rather surprising. The material forms a very steep circular ring and a steep peak in the centre, and the space between is almost level. When the theoretical form thus arrived at is superimposed on the saucer-shaped depression caused by the explosion, the resulting structure is almost exactly that of a typical lunar ring. There are only minor differences that must be taken into account. The real case is closely approximate to the ideal one. The first difference is that the layer of material radially in the way of the explosive is least in the direction directly above it and increases outwards in all directions. Therefore a larger quantity of matter is pushed sideways than is thrown upwards. The result is that the mountain-ring tends to dwarf the central peak. The next point is that the

falling material cannot form vertical cliffs. That which flies farthest reaches the surface in directions making angles of 45 degrees with it. This gives a maximum value for the outer slope. The inner one is determined by the nature of the material. The fragments roll or slide down till they rest at the natural angle. The fact that the, material is not ejected exactly from a point is of little consequence as the size of the meteorite is very small in comparison with the crater it forms.

The Size of the Meteorites

The diameter of the crater produced by an explosion depends on the velocity with which the matter is ejected. Gravitation on the moon having only one-sixth of its value here, and there being no air to oppose the flight, reasonably small velocities can produce surprisingly large craters. In every case the velocity required is only a fraction of a mile per second.

The following table gives some of the values. Let V denote the velocity of ejection in miles per second, and D the diameter of the resultant crater in miles.

V.	D.	V.	D.	V.	D.	V.	D.	V.	D.	V.	D.
0.01	0.197	0.06	7.09	0.11	23.8	0.16	50.4	0.21	86.9	0.26	133
0.02	0.788	0.07	9.65	0.12	28.4	0.17	56.9	0.22	95.3	0.27	144
0.03	1.77	0.08	12.61	0.13	33.3	0.18	63.8	0.23	104	0.28	154
0.04	3.15	0.09	16.96	0.14	38.6	0.19	71.1	0.24	113	0.29	166
0.05	4.92	0.10	19.70	0.15	44.3	0.20	78.8	0.25	123	0.30	177

Thus for even the greatest of the lunar craters the material need not have been ejected with a speed of more than three-tenths of a mile per second.

Take for instance the case of Copernicus, which is fifty-six miles across. The velocity of ejection required is about 0.17 mile per second. The velocity of the meteorite may have been 250 times as great. The energy of the meteorite per unit-mass would then be 62,500 times that of the ejected fragment. Making allowance for energy lost in other ways, the material thrown out may have been fifty or sixty thousand times as massive as the meteorite. An estimate of the quantity of material in this great ring suggests that

the meteorite which caused it may not have been as much as a mile in diameter.

If moving more slowly the meteorite must have had a greater mass. But alterations of mass or of velocity would change the proportions of the crater. High velocity tends to form a wide ring; great mass to produce a deeper cavity and more substantial walls.

The Lunar Seas

The seas differ from the craters not only in size but also in the nature of their floors. The craters show no sign of lava. The action which caused them seems to have been too sudden for any appreciable melting to take place. The seas, on the other hand, look as if they had been swept by very liquid molten material. This suggests that the impact of a much more massive meteorite, or of a meteoric swarm, broke through the crust whilst the interior was still liquid and deluged a vast circular area with fiery spray. This would almost or entirely obliterate all the craters which previously existed in the area. A rough calculation seems to show that a meteorite four miles in diameter, or a swarm of fragments of equivalent mass, might have formed the great ring of Mare Imbrium if their speed was over forty miles per second. If the speed were lower, a greater mass would be required—one of twenty miles a second, requiring a meteorite seven miles in diameter; and one of ten miles a second, a meteorite with a diameter of eleven miles.

Whilst the craters are evidently of many widely different ages, the lunar seas have rather the appearance of having been formed contemporaneously. Mare Imbrium and Mare Serenitatis, for instance, meet one another with hardly any noticeable difference of level.

There is a possible explanation of such a coincidence. If, as has sometimes been suggested, the minor planets are the fragments of a planet rent asunder by the explosion which followed the impact of an immense meteorite or planetoid, these fragments must have been scattered in all directions. But since the velocities impressed on the fragments would be combined with and dominated by the original velocity of the planet in its orbit, the majority of the new orbits would be near to the ecliptic plane. Many of the fragments in their

initial flight would be collected by the planets and their satellites. Those that struck the moon would reach it almost simultaneously, breaking the lunar crust, exploding in the liquid below, and deluging surrounding areas with gigantic fountains of molten lava. This lava, flowing back, would fill and hide the vents through which it came.

Why the Lunar Seas are Dark

If seas and craters are all of meteoric origin it may well be asked why the seas are dark and the craters light. This appears to depend on the state of the ejected material, whilst this in turn depends on where the meteor explodes. If this is in the solid crust, or amongst the fragmentary material lying upon it, an ordinary crater will be formed. The ejected rock will be shattered and pulverized, and much of it reduced even to fine rock-flour, such as that found around Meteor Crater in Arizona. Whatever the nature of the original rock, this rock-flour will have a high reflecting-power and the crater will appear to stand out brightly on a light ground. Very different is the result when the meteorite reaches the molten interior. The deluge of fiery rain washes the surface, obliterates existing forms, and melts the fragmentary covering. This lowers the surface to some extent, and smooths off most of its irregularities. Now lavas are generally dull and black in appearance, so it is not surprising that these plains swept by molten rock have such a low reflecting-power.

The Rays

Of all the features of the moon the rays diverging from Tycho, Copernicus, Kepler, and several other craters are the most mysterious. They are neither elevations nor depressions, for they cast no shadows under any illumination. They extend for many hundreds of miles, practically along the arcs of great circles. They are not diverted from their course by craters or any other obstacles. They are seen most clearly when the sun shines directly down on them, and they become obscure, or even disappear altogether, when the lighting is oblique. Under full illumination they are distinctly

lighter than the rest of the surface. They very gradually thin out at great distances from their point of divergence.

Some regard these rays as splashes. But it is not easy to imagine splashes following great circular arcs for hundreds of miles. Some take them to be lava-streams; but how could such streams keep their course regardless of differences of level, and in spite of all obstacles in their way? A more reasonable suggestion is that they are sheets of lava that welled up from gigantic radiating cracks. But how were such cracks formed? And if the lava came up through them, why has it not formed any dykes, which cast shadows? Why, again, are they brighter and not darker than their surroundings?

The following explanation seems more plausible than those mentioned above: In the early birth-hours of the solar system, when the moon was first separated from the earth, both were probably in a liquid state. Being a much smaller globe, the moon cooled far more quickly and developed a crust whilst the earth was still entirely molten. All the time both bodies were subject to an intense bombardment of meteorites of all sizes. As long as the moon was liquid they left no trace, but as soon as a crust was formed there were two possibilities: a meteorite might explode in this solid crust or in its fragmentary covering, or it might pierce the crust and explode in the liquid below. Now, as the crust thickened it became more and more difficult for a meteorite to break through it. At last a stage was reached in which a particularly rapidly moving meteorite, after passing through the loose fragmentary covering, might deliver a blow of such violence as to produce long radiating cracks in the solid crust. The explosion of the meteorite would then send an intense wave of hydrostatic pressure through the liquid interior. Superheated liquid, forced through every crack, would be turned into spray and vapour, and would then condense in the crystalline form on the fragments strewn over the solid crust, these fragments being the result of innumerable previous explosions. The whole action would be little more than momentary at any particular spot. The fragments would be hardly, if at all, disturbed, and no melting would take place. They would simply be coated over with a thin crystalline deposit, from which afterwards there would be nothing to remove. The cavities between the fragments would be

as large and as numerous as before, and an oblique light would not be able to penetrate into them. A vertical sun, on the other hand, would shine down into every hollow and light up the crystals there. According to this theory the cracks need not be wide. The ejected vapour would spread in all directions until it condensed. Thus quite an insignificant quantity of material might be able to produce an astonishing effect, giving a high reflecting-power to fragments scattered fairly widely along the line of each crack. Since the wave of compression passed rapidly through the whole of the liquid interior, the effect should be noticeable as far as the cracks themselves extend.

REVIEW OF PUBLICATIONS

A Manual of Celestial Photography, by E. S. King. 177 pages, $5\frac{1}{2} \times 7\frac{1}{4}$ inches. Boston: Eastern Science Supply Co., Price, $3.00.

Professor King's experience in celestial photography at the Harvard College Observatory has been very great and has enabled him to put together in a small volume many useful hints and guides. The earlier chapters are devoted to interesting the beginner in getting started at celestial photography and to starting him on the right road in regard to the all important matter of keeping records of his work. Chapters five to ten treat the adjustments of the telescope, the investigation of the driving mechanism, types of mounting and hints on guiding. Chapters eleven to thirteen discuss the plates to be used, the dark room and its equipment, and the development and care of the plates. Chapter fourteen gives a brief synopsis of the photography of stellar spectra. This chapter is too brief but it is very good as far as it goes. Chapter fifteen contains some useful material on making prints, lantern slides and enlargements. Chapters sixteen to eighteen are addressed to amateurs with small portable telescopes and describe ways that he may adopt his instrument to photography. Suggestions as to objects he may photograph are given. The remainder of the book from chapter eighteen on is a little more technical and treats of the action of the light on the plate, photographic wedges and colour scales, the photometry of stellar images and methods of measuring the images. In addition to the actual material in the book, which is well selected and based on the author's experience, there are numerous leading references to more elaborate works. The only criticism of the book I would make is the price which is high, considering its small size and the number of illustrations.

R. K. Y.

Geschichte der Sternkunde von Ernst Zinner. xi, 671 pages, $6\frac{1}{2} \times 9\frac{1}{2}$ inches. 13 plates and 54 figures. Berlin: Springer. Price (cloth), RM 21.80, 1930.

This history of astronomy is constructed somewhat differently

from any other with which the present writer is acquainted. In succession the author analyses the development of the astronomical ideas and the observational accomplishments of the Egyptians, Babylonians, Greeks, Romans, Jews, Persians, Indians, Chinese, East-Asians (outside China), the aborigines of various countries, the Mayans, Arabians, the Germanic peoples up to modern times, the Celts and the Slavs. Then follows a discussion of works on the history of astronomy and after this are lists of historical and biographical works.

The author's usual method, in the case of each nation, is to discuss their notions on time and its reckoning, their ideas on space, their views on the motions of the heavenly bodies, their beliefs as to the nature and significance of the stars, and their observatories and scientific apparatus. By treating each people in this systematic way an immense amount of information is given of the growth of astronomy throughout the centuries.

Full indexes at the end allow immediate reference to any subject or the work of any person. The book is intended both for the professional and the amateur astronomer. In the plates and the text illustrations are reproductions of interesting old instruments, manuscripts and scenes. The author is director of the Remeis Observatory, Bamberg; and the book is produced in the excellent style of the house of Springer.

C. A. C.

The Mysterious Universe, by Sir James Jeans. ix, 154 pages, 4¾ × 7¼ inches with 2 plates. Toronto: Macmillan Co. of Canada. Price, $1.00. 1930.

This little book contains an expansion of the Rede Lecture delivered before the University of Cambridge in November, 1930. It is, in a way, a sequel to the author's book *The Universe Around Us*, of which, we are told, more than 40,000 copies have been sold. This one will undoubtedly have an equally wide circulation.

There are five chapters: The Dying Sun, The New World of Modern Physics, Matter and Radiation, Relativity and the Ether, Into the Deep Waters. The first four give a masterly presentation in 114 pages of the findings of modern physical science. Here we have pictures of myriads of suns distributed throughout space;

the birth of the solar system; the peculiar behaviour of the carbon atom; the development of the quantum theory and the deduction of the principle of indeterminacy (according to which "nature abhors accuracy and precision above all things"); the combination of corpuscles, waves and electrons; relativity and the ether. Indeed the author surveys the whole field and places its contents before us for consideration.

In the concluding chapter the author attempts a philosophical explanation of the problem presented. Perhaps the following quotation (p. 148) may fittingly close this brief review of an impressive and thought-producing book.

> To-day there is a wide measure of agreement, which on the physical side of science approaches almost to unanimity, that the stream of knowledge is heading towards a non-mechanical reality; the universe begins to look more like a great thought than a great machine. Mind no longer appears as an accidental intruder into the realm of matter; we are beginning to suspect that we ought rather to hail it as the creator and governor of the realm of matter—not of course our individual minds, but the mind in which the atoms out of which our individual minds have grown exist as thoughts.

"The things which are seen are temporal; but the things which are not seen are eternal." Truly a mysterious universe.

C. A. C.

NEWS AND COMMENTS

Astronomers the world over will rejoice at the news of the magnificent gift of a large observatory to the University of Toronto. Professor C. A. Chant, who made the announcement, stated that the observatory will be known as "The David Dunlap Observatory", erected as a memorial to the late David Dunlap by his widow, Mrs. D. A. Dunlap and their son, Moffat Dunlap, of Toronto. It will be located not very far from Toronto, though the site has not been finally determined. There will be a 74-inch reflecting telescope mounted under a 60-foot metal dome. Besides this there will be a fine observatory building, presumably in stone, with additional equipment. The contract for the telescope has been given and it is expected to be in operation in two and a half years. The grounds will be made into a park, to be developed by the Faculty of Forestry of the University.

A 65-foot planetarium has been donated by Mr. S. S. Fels to the museum of the Franklin Institute. Mr. James Stokley has severed his connection with *Science Service* to become director of the astronomical section of this museum.

Professor Albert Einstein arrived in New York on December 11th, and after a few days proceeded by way of Panama to pay a visit to Pasadena and Mount Wilson Observatory. The newspapers reported that while in New York many people claimed relationship to the distinguished scientist. On which the *Ottawa Citizen* remarked: "A new phase of the relativity problem". Professor Einstein has accepted an invitation to become Cecil Rhodes Memorial Lecturer at the University of Oxford, where he will reside during the coming summer term.

Dr. H. M. Ami, a past-president of the Ottawa Centre of the Royal Astronomical Society of Canada, died in France on January 6. Dr. Ami was for many years on the staff of the Geological Survey, but of late years was head of the Canadian School of Pre-History in France, making yearly trips abroad to conduct investigations concerning pre-historic man in the Dordogne region about Les

Eyzies, where he made many interesting discoveries. He had an enthusiastic interest in all branches of natural history, and was one of the earliest members and guiding lights of the Ottawa Field Naturalists' Club. He preserved many photographic records of the face of nature about Ottawa before it was disfigured by man. His kindly and enthusiastic nature has left an indelible imprint on a wide circle of friends.

Father J. S. Ricard died at the infirmary of the University of Santa Clara, California, on December 8 last, at the age of eighty years. He was known as the "Padre of Rains", as he had established a relationship between the passage of sunspots across the solar disc and the time of the appearance of storms on the Pacific coast.

REDEL.

Notes from the Dominion Astrophysical Observatory

November and December were about average months for observing, the former being a little below whilst the latter was a little above the average. On 12 nights in November 74.5 hours observing was secured as against the twelve-year average of 82.8 hours for the month. For December the twelve-year average is 64.4 hours and 76.7 hours was obtained this past year.

Taking the year as a whole, while it was somewhat poorer than last year, which constituted a record here since the observatory was opened, it nevertheless was much above the average. The twelve-year average shows 207 nights with 1272.4 hours observing; this past year shows 217 nights with 1415.3 hours observing. To these figures should be added, of course, proportionate amounts for the two hours each Saturday night devoted to visitors. The local meteorological statistics are in agreement with our records as the number of hours sunshine was 114 above the average. This is the third dry year in succession, the total precipitation being 18.85 inches or 8.25 below the average.

There were approximately 267 visitors in November and 207 in December making a grand total for the year of 33,318. Last year's total was 39,027. One evening in November we had a visit from Lord Stonehaven, the retiring Governor-General of Australia, who

was accompanied by Lady Stonehaven and Lieutenant-Governor Bruce and his niece, Miss McKenzie. They all seemed interested in the celestial objects seen through the 72-inch telescope.

Equipment has been received from the Ottawa observatory for the reception of wireless signals and an aerial has been set up between the dome and the water tank. When installed it will be simpler keeping the clocks correct than under the old system, where accurate time was secured by phone from the Gonzales' observatory.

W. E. H.

A PRAYER FOR LIGHT*

O, wondrous, regnant Evening Star,
Thrilling our vision from afar!

From your clear outpost there on high
Future and Past are in your eye;

Backward, down the far, dim way
You see behind the breaking day,

And, Forward, through the encompassing light,
Beyond the baffling shades of Night.

You know the country whence I came
Through infinite cycles without name;

You know the way my soul must wend
Through nameless cycles without end.

So vast a knowledge in your heart,
With one small word you will not part;

So much of mystery in your breast,
One flash would set the world at rest;

One broken shaft of Truth from thee,
And all the world's blind eyes could see!

BERTRAM W. HUFFMAN.

Langdon, Alta.

*"I am enclosing a brief song to Jupiter, at present so transcendently beautiful just above my prairie farm."—*In a letter to the Editor.*

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Einstein and His Visit to America

Anything relating to Professor Einstein is world news, and just recently more than ordinary attention has been given to him. At the present time he is in Pasadena as a research associate of the California Institute of Technology which appears to be the Mecca to which all the specially distinguished scientists make pilgrimages. When at New York, Professor Einstein was almost overwhelmed by reporters and photographers, and the clever answers he gave to the questions, pertinent and impertinent, put to him, called forth high admiration. Apparently he was no absent-minded, unobservant dreamer.

Perhaps I might quote the following contributions to Einsteiniana. The first is from the *Toronto Globe* (December 20, 1930) and is by an "English-Canadian", who has contributed a series of clever *jeux d'esprit* to that newspaper. For the benefit of our foreign readers it may be stated that the Mr. Bennett mentioned is the recently elected prime minister of Canada.

Alice in Blunderland

"I've been invited to the States to meet Professor Einstein," said the Mock-turtle. "What should I talk to him about?"

"Sculpture," replied the Gryphon. "I remember when some of his work was first shown in London."

"That was Epstein," Alice interposed. "Einstein is the man who discovered —invented—relativity."

"What's that?" the Mock-turtle asked.

"Relativity is—" the Gryphon answered and then stopped. "You tell him," he said to Alice. "You're younger than I am."

"It's difficult to explain," said Alice. "It can be talked about only in terms of mathematical formulae."

"I don't know what you mean by that," said the Mock-turtle.

Neither did Alice, quite, but not wishing to reveal her ignorance, she tried hard to remember some mathematical terms.

"Well, like 'A multiplied by A equals A-square'," she said.

"Any one can tell you're English," the Mock-turtle said, rudely, "by the way you drop your aitches. You mean hay multiplied by hay."

"Equals haystack," added the Gryphon.

"I don't mean anything of the kind," Alice protested, "and it's no use trying to explain to you, anyway. There are only ten men living who can understand the Einstein theory."

"Or his sculpture, either," the Gryphon added, obstinately.

"Sounds to me like one of Premier Bennett's election speeches," said the Mock-turtle. "Why can't people understand it?"

"Because of its profundity," Alice told him.

"It's not a Bennett speech, then," said the Mock-turtle, and added: "I think I shall tell Einstein I've invented a theory which is so profound that I can't even understand it myself; then as neither of us will be able to discuss the other's ideas we can just talk about the weather."

Neither of them had noticed a young man who had drawn near, and was listening to their conversation, but now the stranger spoke:

"If you want the low-down on this Einstein dope," he said, "I can give it to you. Relativity means that any natural phenomenon must be examined in its relation to all other natural phenomena—want to be careful about that 'non' and 'na'—and as space folds back on itself it follows that light rays can be bent—that's how we come to talk about arc lights, I guess, on account of them being bent like a part of a circle—which disproves Newton's theory, so that relatively everything's just the same as if Newton and Einstein hadn't ever theorized on anything."

"Thank you very much," said the Mock-turtle. "I suppose you are the ten men Alice was just telling us about."

"Say, you don't fall for that stuff, do you?" asked the stranger. "It would take a better man than Einstein to invent anything a newspaper reporter couldn't explain in a couple of sticks."

The second quotation is from *Public Opinion* (London) and reveals another side of the great scientist.

EINSTEIN'S IDEALS

There is one thing we do know: that man is here for the sake of other men —above all for those upon whose smile and well-being our own happiness depends, and also for the countless unknown souls with whose fate we are connected by a bond of sympathy.

Many times a day I realize how much my own outer and inner life is built upon the labours of my fellow men, both living and dead, and how earnestly I must exert myself in order to give in return as much as I have received.

My peace of mind is often troubled by the depressing sense that I have borrowed too heavily from the work of other men.

The ideals which have always shone before me and filled me with the joy of living are goodness, beauty and truth. To make a goal of comfort or happiness has never appealed to me; a system of ethics built on this basis would be sufficient only for a herd of cattle.

Possessions, outward success, publicity, luxury—to me these have always been contemptible. I believe that a simple and unassuming manner of life is best for everyone, best both for body and mind.

The Ten Greatest Astronomers

Some time ago Professor F. C. Leonard, of the University of California at Los Angeles, was asked to supply the names of the ten greatest astronomers in order to have them placed on a new building. Arranged in "the order of decreasing greatness" they are: Newton, Copernicus, Galileo, Kepler, Einstein, Hipparchus, W. Herschel, Kirchhoff, Ptolemy and Tycho Brahe. Professor Leonard gives reasons for his selection in a recent number of *Popular Astronomy* and confesses some uncertainty as to the order of greatness in a few cases but none regarding who the ten are.

The Drought of 1930 in the United States

According to Chief Marvin of the U.S. Weather Bureau the drought of the summer of 1930 in the central States was unprecedented. There was a prolonged stagnation of air over nearly the whole of the United States, but no reason can be assigned for it. Based on reports up to August 31, Dr. Marvin says that not a single State east of the Rocky Mountains, during the three principal growing months, had as much as the normal precipitation, and some half dozen of them had less than half the normal amount. Further, the summer season was generally warm, while from the middle of July to the middle of August the temperature was abnormally high and it greatly intensified the effect of deficient moisture. The growing season from March to August as a whole was the driest on record over a large area.

In the Canadian north-west the summer was not as dry as in 1929 and still farther north there was abundant precipitation. According to reports from the Canadian Meteorological Service the summer resembled that of 1894. In June, 1930, the rainfall in northern Ontario and northern Quebec was unprecedented.

Rain-making Devices

In connection with the previous note it will be interesting to give the following information about patented devices for producing rain. It was supplied by *Science Service.*

If you could make rain in any desired amount to order, you would undoubtedly become the most famous person in the world, besides earning a fabulous fortune. The severe drought brought its usual crop of professional rain-makers seeking to swindle the credulous farmer, who in his desperate straits is willing to take a chance on almost anything that may bring relief to his sun-baked, withering crops. No method has yet been devised which will produce rain in a sufficient quantity to make it practicable during a severe drought, but unfortunately not all farmers know this.

The professional rain-maker is a shrewd salesman who knows how to play on the credulity of human nature. He may, for example, enter into a contract with a farmer promising him rain in a week or ten days for which he is to receive five thousand dollars. The rain-maker will then set up some formidable-looking apparatus which discharges electric sparks or chemicals in the air. He may explode shells containing gunpowder or nitroglycerine. Under ordinary circumstances rain is bound to come sooner or later, and the rain-maker can very well gamble on this chance, for he has nothing to lose. As soon as rain comes he credits the performance to himself and, of course, demands the sum specified in his contract.

Rain-makers have been careful to protect their methods and devices by obtaining patents from the government. Daniel Ruggles obtained a patent in 1880 for making rain by sending up one or more balloons carrying explosive cartridges and torpedoes which are detonated by an electric wire trailing on the ground. His theory is that the explosion produces a concussive force which condenses the moisture in the air, thus producing rain. There is actually no scientific basis in this theory. During the war immense quantities of explosives were detonated, but no appreciable quantity of rain was caused by those explosions.

Another patent issued in 1891 to Louis Gathmann first forms rain clouds by spraying liquid carbon dioxide gas high up in the air. The evaporation of the carbon dioxide cools the air, condensing the moisture it contains, forming a cloud and finally rain. This method appears plausible at first, but in order to cool large quantities of air so as to produce any appreciable condensation of moisture, extremely large quantities of liquid carbon dioxide would have to be used, the cost of which would be prohibitive. The rain thus produced would not save enough crops to pay for the expense involved.

Several patents have also been granted for balloons equipped with sharp metallic points in order to discharge electricity in the air. John Potts, for instance, obtained a patent in 1913 for a balloon having many sharp spurs on its surface. These points are attached to a wire which is grounded. Another patent, granted in 1918, uses a similar device. The inventor explains his theory in the following language:

"The atmosphere is known to contain transient zones of electrified air, and it is also known that aqueous particles constituting clouds are invariably charged with electricity and that the potential distribution throughout such atmospheric zones and clouds is usually uneven. It is also known that the sign and the potential gradient of regions of the atmosphere are varied or altered by these charged zones of clouds. I have discovered that if the potential gradient between earth and such atmospheric zones and clouds is diminished or canceled, particularly at times preceding rainfall, or at times when rain is falling, rainfall is procured or stimulated." Unfortunately although this theory sounds plausible it does not in practice produce rain.

Numerous devices, such as those described, were offered to hundreds of farmers to break the drought. The officials of the United States Weather Bureau brand them as pure fakes, and the men who are enriching themselves at the farmers' misfortune are nothing but scoundrels.

Science has not yet discovered all the facts of meteorology. We are still at the mercy of the elements, just as our ancestors were thousands of years ago, except that we have provided ourselves with better shelter. Until our knowledge of weather is more complete than it is at present, it will be almost impossible to control or to make rain when we need it, because we do not understand all the underlying causes. Until then, farmers can do nothing in times of drought, in spite of the claims of inventors or professional rain-makers.

C.A.C.

MEETINGS OF THE SOCIETY

November 18.—A regular meeting was held in the Physics Building of the University of Toronto at 8 p.m. Mr. J. R. Collins in the chair. There were four elections to membership:—

Harvey Kruspe, 211 Carlton St., Toronto.
W. F. Whittier, 18 E. Arch St., Mansfield, Ohio.
P. H. Reedy, 1600 College Avenue, Terre Haute, Indiana.
Dr. Richard Hamer, 117 Oxford St., Halifax, N.S.

A letter of sympathy, forwarded on behalf of the Society to the family of the late Major A. D. Armour, K.C., was read, also the reply thereto. The letter is as follows:—

October 29th, 1930.

Mrs. A. D. Armour,
23 Chicora Ave.,
Toronto.

Dear Mrs. Armour:

The Royal Astronomical Society of Canada places on record its sense of the loss it has sustained in the death of your husband, Major A. D. Armour, K.C., one of its members.

Major Armour joined the Society only recently, but during his brief membership evinced a keen and most intelligent interest in its activities. He had procured a telescope, and was very much interested in the observational part of the work, applying himself to observations of stars and planets with much interest. He was also very deeply taken with the written and theoretical part of astronomical learning, and was excellently well informed in regard to that vast store of learning accumulated by specialists in that branch of our work.

He possessed a very penetrating and comprehensive mind and in his loss our Society has to mourn an exceedingly talented and promising member.

We extend our deep and genuine sympathy to you and your family on the occasion of his sad and, to us at least, unexpected demise, whilst you, in your immeasurably greater loss, will yet rejoice that you have been privileged to accompany him thus far in his journey through life, taking comfort that his being was filled with a deep regard for the Works of the Greatest Friend of all.

Yours very sincerely,

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA,
Per L. GILCHRIST, *Secretary*.

Mr. H. L. Rogers gave a very good description of the constellation Pegasus. The evening's lecture, "Weather forecasting for the Air Service", with special reference to the airship R-100, was given by Mr. J. Patterson, M.A., Director of Meteorological Service of Canada.

The lecturer introduced his subject by referring to a speech of the late Lord Thomson wherein it was remarked that when the engineer had completed his task of constructing an airship, an equally or more difficult task faced the meteorologist, in order that the ship may navigate as safe a path as possible. The engineer's task is the easier in that his tests may be completed in the laboratory, but no such facilities are available to the meteorologist who must take the weather as it comes.

The lecture was conducted throughout with the aid of slides. Among these were shown the actual weather charts used on the recent voyage of the R-100 to Canada and which were presented to Mr. Patterson by Mr. Giblett, of the staff of the R-100, who unfortunately was lost in the disaster to the R-101.

The visit of the R-100 instituted the first organized meteorological service rendered to airships. The U.S. Weather Bureau supplied much valuable information and maintained an interest in the proceedings. The British authorities supplied the forecasts during the eastern section of the journey, the balance being taken over by the Canadian Meteorological Service. These arrangements also obtained during the return voyage.

It was necessary to receive weather conditions from many sources in order that as accurate forecastings as possible could be made. Some of these reports came and were transmitted by devious routes; those from Greenland were picked up at Belle Isle, forwarded to Toronto, thence to Washington, Arlington and England.

The reports given to the airship undoubtedly proved of assistance to the navigators, and the details of the voyage as supplied by Mr. Patterson convinced his audience that the safety of these dirigibles, apart from structural defects, depends almost wholly upon these forecasts. Even then, totally unexpected conditions may arise, as was instanced by the severe "bumping" the airship received whilst in the St. Lawrence river valley, the result of purely local conditions, due probably to a fall in temperature. The lecturer outlined the conditions obtaining to a safe mooring of an airship, where the buoyancy of the air, dependent upon temperature and the force and direction of winds are the chief factors.

A few charts were shown of the weather conditions over Europe at the time of the R-101 disaster, and from these it was evident that the airship was in the midst of a stormy area which was spreading southwards.

A vote of thanks to Mr. Patterson for his extremely interesting lecture was proposed by Mr. A. F. Hunter and seconded by Mr. H. L. Rogers. Some interesting discussion followed.

S. C. Brown, *Recorder.*

Correction to The Observer's Handbook, 1931

On page 71, line 10, after the word "respectively" add "and change the sign."

The Royal Astronomical Society of Canada

OFFICERS FOR 1930

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